Cash Holdings and Credit Risk

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Intuition suggests that firms with higher cash holdings should be “safer” and have lower credit spreads. Yet empirically, the correlation between cash and spreads is robustly positive. This puzzling finding can be explained by the precautionary motive for saving cash, which in our model causes riskier firms to accumulate higher cash reserves. In contrast, spreads are negatively related to the part of cash holdings that is not determined by credit risk factors. Similarly, although firms with higher cash reserves are less likely to default in the short term, endogenously determined liquidity may be related positively to the longer-term probability of default. Our empirical analysis confirms these predictions, suggesting that precautionary savings are central to understanding the effects of cash on credit risk. (JEL G32, G33)

Common intuition suggests that firms that have larger cash holdings in their asset and investment portfolio should be “safer.” In particular, cash-rich firms should have a lower probability of default and lower credit spreads, other things equal. In this paper, we argue that, in general, other things are not equal, and that the intuitive, but naïve, prediction falls prey to the confounding effects of endogeneity. We show empirically that a conservative cash policy is more likely to be pursued by a firm that finds itself close to distress. As a result, larger cash holdings are empirically associated with higher, not lower, levels of credit risk.
Our theoretical argument can be summarized as follows: The firm is a portfolio of assets, of which cash is one, and the composition of assets in the portfolio depends on the firm’s liability structure. In particular, when the risk of default increases, the firm increases its holdings of liquid assets in response. This adjustment offsets the change in risk, but only partially. As a result, a higher level of cash reflects changes across the firm’s assets and liabilities, but does not necessarily imply a safer firm overall.

We take predictions from this simple argument to the data to explore complex interactions between cash policy and credit risk. Two of our empirical results are particularly striking and counterintuitive. First, when we replicate the reduced-form approach commonly used in empirical studies of credit spreads, we find that a one-standard-deviation increase in the cash-to-asset ratio is associated with an economically significant 20-basis-point increase in credit spreads, after controlling for firm-specific characteristics such as leverage, volatility, and credit rating. Thus, it may appear that higher cash holdings increase credit spreads. The effect is robust and persistent.

Second, we explore the role of liquid assets in empirical default-predicting models, such as Altman’s (1968) z-score.1 While almost all such studies control for balance sheet liquidity, their findings concerning the effect of liquidity on the probability of default are inconclusive and often puzzling.2 When we reestimate such models, we find that the correlation of liquidity with default depends crucially on the time horizon over which default is being considered. The short-term probability of default is lower when liquid asset reserves are large, consistent with the common intuition. However, for horizons longer than one year, the correlation between cash and default reverses sign and becomes positive and strongly statistically significant. It would appear that higher cash holdings increase the long-term probability of default.

What can explain these puzzling empirical findings? We propose a theory based on the endogeneity of a levered firm’s cash policy. In the presence of financing constraints, riskier firms (e.g., those with lower expected cash flows) optimally choose to maintain higher cash reserves as a buffer against a possible cash flow shortfall in the future. In the model, the firm can either invest its cash long term, or retain it as a cash buffer until the firm’s debt comes due. Market frictions restrict the firm’s access to external capital, and default is costly. The firm faces a trade-off between investing more (and getting higher cash flows in the future, conditional on not defaulting) and keeping more cash in reserve (implying a lower probability of a cash shortage and thus a higher chance of survival).

1 Other prominent studies include Ohlson (1980), Zmijewski (1984), Shumway (2001), and Chava and Jarrow (2004).

2 For example, the correlation of the probability of default with the current ratio is positive in Zmijewski (1984) and negative in Shumway (2001), whereas that with the ratio of working capital to total assets is negative in Ohlson (1980) and positive in Hillegeist et al. (2004).
Cash Holdings and Credit Risk

In this model, a change in factors that affect the firm’s credit risk influences spreads and default probabilities through two channels: directly (the “direct” channel), and through the adjustment in the level of cash holdings (the “indirect” channel). For example, a decline in expected future cash flows leads to an increase in the default probability and a corresponding rise in credit spreads. At the same time, the firm responds by optimally increasing its cash holdings, which reduces the probability of a cash shortfall and leads to lower spreads. The model’s main insight is that the direct channel dominates as long as constraints on external financing are binding. As a result, riskier firms have both higher optimal cash reserves and higher credit spreads and long-term default probability. Consistent with this prediction, we find empirically that for speculative-grade firms, cash holdings increase with credit risk, as do credit spreads.

The model also implies that variations in cash holdings that are unrelated to credit risk factors (so that there is no direct effect on spreads) should be negatively related to spreads, in line with the standard intuition. Indeed, we find empirically that the correlation between cash and spreads, as well as that between cash and longer-term default probability, turns negative when we “instrument” the variations in cash by such variables as proxies for managerial self-interest and firm’s long-term investment opportunities.

Finally, the model also predicts that over a short horizon, higher cash reserves reduce the probability of default, consistent with the findings of Davydenko (2012), but may be associated with a higher default probability over a longer period, reconciling the seemingly conflicting evidence of the effect of cash holdings in default-predicting studies.

Our findings highlight the importance of adopting the corporate finance perspective in asset pricing studies. For instance, extant credit risk models typically assume that, should the firm find itself in a temporary cash shortage, it avoids default by costlessly selling new equity, as long as the share price remains positive, rendering cash policy irrelevant.3 This approach is mirrored in empirical credit risk studies, which also do not consider the role of cash holdings (e.g., Duffee 1998; Collin-Dufresne, Goldstein, and Martin 2001; Schaefer and Strebulaev 2008). Our results suggest that theoretical and empirical studies of credit risk (and likely other areas of asset pricing) should account for the endogeneity of corporate financial and investment policies.4 Otherwise, employing some of the most common firm-level “control” variables (such as

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3 This assumption is made in most prominent credit risk models, such as Black and Cox (1976), Leland (1994), Longstaff and Schwartz (1995), Collin-Dufresne and Goldstein (1997), and others. Notable exceptions include recently developed models by Acharya et al. (2006), Gamba and Triantis (2008), Asvanunt, Boudie, and Sundaresan (2010), Gryglewicz (2011), and Anderson and Curverhill (2012), which allow for optimal cash holdings in the presence of costly external financing.

4 Although the endogeneity of firm characteristics is recognized as a major issue in empirical corporate finance and many other areas of economic research (Roberts and Whited 2012), it appears to have attracted less attention in asset pricing studies.
proxies for corporate liquidity) in standard tests (such as predictive regressions of default) may yield economically misleading conclusions.

Our study is related to the stream of papers in corporate finance on the endogenous determination of corporate cash holdings, such as Opler et al. (1999), Almeida, Campello, and Weisbach (2004), and Bates, Kahle, and Stulz (2009). In this literature, the precautionary motive for hoarding cash arises because of financing frictions that restrict firms’ access to external financing. Recently, studies such as Eisfeldt and Muir (2012) have extended this approach to look into the implications of financial constraints for the dynamics of financing and cash holdings. However, extant research does not explicitly link cash holdings to credit risk or credit spreads, as we do. Moreover, we show that precautionary motives for saving cash are of first-order importance even for rated public bond issuers, suggesting that these firms exhibit behavior qualitatively similar to that of more financially constrained firms.

1. The Model

This section develops a model of a firm’s optimal cash policy in the presence of costly default and restricted access to external financing. Our main goal is to show that cash holdings in equilibrium can be positively correlated with credit spreads and default risk, and to discuss the economic mechanisms behind this counterintuitive relationship. We disentangle the intuitive, but naïve, prediction that cash-rich firms should be “safer” from the confounding effects of endogeneity. As discussed in Section 1.2, although the model is stylized, our conclusions are quite general. In an online appendix, we develop a continuous-time model of endogenous cash policy, which delivers the same main results as outlined in this section.

1.1 Model setup

The model features a single levered firm in a three-period investment economy. The firm has both assets in place and growth opportunities. In each period $t$ from 0 to 2, its assets in place produce a cash flow $x_t$. For our purposes, it is important that the interim-period cash flow $x_1$ is random and unknown at date 0. We can write $x_1 = x_1 + u$, where $x_1$ is a known constant and $u$ is a zero-mean random cash flow shock. The probability distribution of $u$ is described by the density function $g(u)$ with support $[u, \infty)$, and with the associated cumulative distribution function $G(u)$ and the hazard rate $h(u)$, defined as

$$h(u) = \frac{g(u)}{1 - G(u)}. \quad (1)$$

Although the firm’s cash flow can be negative, it is bounded from below by investors’ limited liability. We assume that the minimum cash flow shock, $u$, is large enough for the limited liability to be satisfied.
We assume that the hazard rate \( h(u) \) is weakly monotonically increasing. For our purposes, it is sufficient that the cash-flow shock \( u \) is the only source of randomness in the model, and hence we assume that the cash flows at dates 0 and 2 are known. As will transpire below, the timing in the model is such that allowing for a random component in these cash flows would neither alter shareholders’ incentives nor affect our results in any way.

At date \( t = 0 \), the assets in place generate a positive cash flow \( x_0 > 0 \). At this time, the firm has access to a long-term project, which in return for investment \( I \) at \( t = 0 \) yields a deterministic cash flow of \( f(I) \) at \( t = 2 \), where \( f(I) \) is a standard increasing concave production function. Market frictions preclude the firm from accessing outside financing, so that the firm’s disposable cash comes entirely from its internal cash flow. This cash can be invested, either partially or fully, in the long-term project, or retained within the firm as a cash reserve, carried over from date 0 to date 1. We denote the cash reserve as \( c \), so that \( c = x_0 - I \).

At date \( t = 1 \), the firm must make a debt payment of \( B \), which is assumed to be predetermined (a legacy of the past). We also assume that debt cannot be renegotiated due to high bargaining costs; for example, it might be held by dispersed bondholders prone to coordination problems. Failure to repay the debt in full at \( t = 1 \) results in default and liquidation, in which future cash flows both from the long-term investment, \( f(I) \), and from the assets in place, \( x_2 \), are lost. Since the period-1 cash flow, \( x_1 \), is random, there is no assurance that it will be sufficient to repay the debt in full. Moreover, due to market frictions, external financing is unavailable, and hence the debt payment must be made out of the firm’s internal funds. This gives rise to incentives for the firm to retain part of its cash between periods 0 and 1 as a buffer against a possible future cash shortfall, to reduce the probability of default.

The firm’s equityholders maximize the final period’s payoff. The risk-free rate of interest is normalized to zero, and, in the base case, managers act in the best interests of shareholders. Figure 1 illustrates the model’s timeline.

1.2 Discussion

Before proceeding further, we want to stress that the exact specification of the model can vary widely without affecting the results qualitatively, as long as two

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6 This assumption is unrestrictive and often appears in economic applications, such as game theory and auctions (e.g., Fudenberg and Tirole 1991, 267). Bagnoli and Bergstrom (2005) show that the hazard rate is weakly monotonic if the function \( (1 - G(u)) \) is log-concave, which holds for uniform, normal, logistic, exponential, and many other probability distributions.

7 Although firms can choose not only cash holdings but also debt levels, variations in cash holdings are likely to be much larger than those in leverage ratios. To test this conjecture, we use annual Compustat data between 1980 and 2006, focusing on non-financial firms with non-trivial debt amounts (book leverage above 5%). We find that for the median firm, the coefficient of variation (standard deviation divided by the mean) for cash as a proportion of total assets is 0.80, compared with 0.36 for total debt over total assets and only 0.27 for book equity over total assets, with differences significant at the 1% level. Thus, cash holdings are likely to be more easily adjusted than debt levels. Therefore, in our analysis of the optimal cash policy, we treat debt as exogenous.
assumptions are satisfied. First, default involves deadweight costs. (Although we assume that all future cash flows are lost in default, an extension to a partial loss is straightforward.) Second, external financing cannot be raised against the full value of future cash flows, meaning that there are some financing frictions at date 1. If the firm can pledge a large enough fraction of its future cash flows as collateral, then current and future cash holdings can be viewed as time substitutes, and there is no role for precautionary savings of cash. In reality, the condition of partial pledgeability is likely to be universally met. While the base-case model assumes that external financing is prohibited altogether, Subsection 1.6 extends the model by allowing the firm to borrow up to a certain fraction of its future cash flows at \( t = 1 \), and shows that our main results hold as long as financing constraints are sufficiently binding.

A related feature in our model is that a non-trivial part of the cash flow from the current investment will be realized only after a portion of the outstanding debt is due, giving rise to a time mismatch between cash flows and liabilities. Effectively, the expected long-term cash flow can neither be pledged nor used as cash to cover debt obligations. In practice, most capital expenditure items are likely to satisfy this requirement, because they usually generate cash flows after some non-trivial debt payments. In the base-case model, we assume that the investment outcome is realized in full only at date 2. This assumption can be relaxed so that the investment also can generate a cash flow at date 1. What is needed is a non-trivial fraction of cash flows expected after the debt payment is due, so that firm survival at the intermediate stage is a worthy option.

In general, in addition to saving and investing, firms can also distribute some of the cash to their shareholders. Fixed, pre-committed dividends at \( t = 0 \) amount to a reduction in the net cash flow \( x_0 \), and can be easily incorporated in the model. Although modeling an optimal dividend policy at \( t = 0 \) would complicate the analysis considerably by introducing a second choice variable, the intuition on the effect of optimal dividends is as follows. Most firms in
Cash Holdings and Credit Risk

the model would choose not to pay any dividend, because the cash can be profitably invested in the long-term project. However, if the firm is very risky, the precautionary motive for saving cash can be dominated by the incentives to engage in “asset substitution,” i.e., to pay out a large immediate dividend at the expense of making the firm even riskier. In our base-case model, we assume that in order to prevent such behavior, discretionary dividends are prohibited by covenants.

If the firm has access to external capital at \( t = 0 \), it can choose to raise additional capital at that time to increase its investment and/or cash holdings. Selling equity can be viewed as making a negative dividend payment. By the same logic as above, in our model a firm should normally find it desirable to raise equity, as long as the marginal value of an additional dollar of investment is greater than one. However, if the firm is very risky, instead of contributing additional equity, shareholders would have incentives to pay themselves a dividend and not invest long-term. By contrast, raising debt maturing at \( t = 1 \) that is more senior than the existing debt solely to increase the cash reserve is value-neutral in this setting, as the increase in cash is exactly offset by the increase in the required debt repayment (i.e., cash is negative debt in this setting). In our base-case model, we assume that financing constraints at \( t = 0 \) preclude the firm from accessing any additional financing. Allowing for optimally chosen financing ex ante could be an interesting extension of our model.

To assert the generality of our main results, we have constructed a fully dynamic continuous-time model that relaxes some of the base-case assumptions. In that model, the firm is financed by equity and infinite-maturity debt with a continuously paid coupon. In contrast with the base-case model, investment is fixed, but dividends are endogenously determined. The firm’s cash flow is first used for debt service. The remainder can be paid out as a dividend or retained within the firm as a buffer against a possible cash flow shortage. The firm faces a trade-off between higher dividends and higher cash reserves that reduce the probability of default. Although this setting is very different from the base-case model, its main predictions regarding the relationship between cash and credit risk are very similar. A full description of this model can be found in the online appendix, also available from the authors upon request.

Returning to the base-case model, note that cash reserves are costly to the firm because they are financed by reductions in long-term investment. This way of modeling the cost of cash holdings is convenient, but by no means unique. For example, Anderson and Carverhill (2012), Asvanunt, Broadie, and Sundaresan (2010), and Kim, Mauer, and Sherman (1998) assume that cash has a convenience yield because of taxes or agency issues. Thus, forgone investment here should be understood more broadly as the opportunity cost of cash. For example, in our continuous-time model outlined above, investment is fixed but the dividend policy is optimally determined. In that model, the opportunity cost of retaining cash is represented by the value of unpaid dividends.
1.3 Optimal cash policy

At date 0, the firm faces the following trade-off between investing its cash in the long-term project and retaining it until the next period. On the one hand, larger retained cash holdings imply lower investment. This results in lower future cash flows generated by the long-term investment conditional on survival in the interim period. On the other hand, an increase in cash holdings reduces the probability of a cash shortage at date 1, and thus increases the likelihood that the firm survives until date 2 to reap the benefits of the long-term investment. The firm’s optimal cash and investment policies balance these costs and benefits of cash.\(^8\)

The amount of cash available for debt service at date 1 is \(c + x_1\), where \(c = x_0 - I\) is the cash reserve and \(x_1 = x_1 + u\) is the interim-period cash flow from assets. The “default boundary,” or the minimum cash flow shock that allows the firm to repay \(B\) in full and avoid default, is\(^9\)

\[
u_B = B - x_0 + I - x_1.
\]

The default boundary increases in the level of debt and sunk investment, and decreases in realized date-0 and expected date-1 cash flows. For all realizations of \(u\) between \(u_0\) and \(u_B\), the firm defaults and equityholders are left with nothing. The total payoff to equityholders is the sum of the cash flows from assets in place and the payoff from the long-term investment, less the invested amount and the debt repayment, provided that the firm does not default on its debt in the interim. The market value of equity is therefore

\[
E = \int_{u_B}^{\infty} [x_0 - I + x_1 + u - B + f(I) + x_2]g(u)du,
\]

which can also be rewritten intuitively as

\[
E = \int_{u_B}^{\infty} ([u - u_B] + f(I) + x_2)g(u)du.
\]

Here, \(u - u_B\) is the amount of cash left in the firm after \(B\) is repaid, and \(f(I) + x_2\) is period-2 cash flow, conditional on the firm not defaulting in the interim.

Managers maximize the value of equity by choosing the optimal level of investment. From Equation (3), equityholders’ optimization problem yields the following first-order condition:\(^{10}\)

\[
\frac{\partial E}{\partial I} = \int_{u_B}^{\infty} [-1 + f'(I)]g(u)du - [x_0 - I + x_1 + u_B - B + f(I) + x_2]g(u_B)\frac{du_B}{dI} = 0.
\]

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\(^8\) Covenant restrictions may prevent the firm from investing at the optimum. Should this be the case, the firm may end up with excessive cash reserves (from equityholders’ point of view) and our results are likely to be strengthened.

\(^9\) Without loss of generality, we assume that \(u_B \geq u\).

\(^{10}\) It is easy to show that the second-order condition for maximization is satisfied. We also assume that initial cash holdings are high enough for the first-order condition to yield an interior solution.
Substituting the expression for $u_B$ from Equation (2) and rearranging, we can rewrite this first-order condition as

$$f'(I) = 1 + (f(I) + x_2)h(u_B). \quad (6)$$

In the first-best case of unrestricted investment, the standard maximization solution would yield $f'(I) = 1$. In the presence of costly default and restricted access to outside financing, investment is below its first-best level. This follows from Equation (6), given that the right-hand side is greater than one. To understand the intuition behind the optimal investment and cash policies, notice that the first-order condition (5) can be rewritten as follows:

$$\left(f'(I) - 1\right) \times (1 - G(u_B))dI = (f(I) + x_2) \times g(u_B)du_B. \quad (7)$$

The left-hand side in Equation (7) is the net value gain from increasing investment by $dI$, which is equal to $(f'(I) - 1)dI$, multiplied by $1 - G(u_B)$ to condition on the probability of survival. The right-hand side gives shareholders’ marginal expected loss from default, equal to the value of equity at the default boundary, $f(I) + x_2$, multiplied by the marginal increase in the probability of default due to the shift in the default boundary, $g(u_B)du_B$.

The market value of the firm’s debt, $D$, is

$$D = B - \int_u^{u_B} [B - (c + x_1 + u)]g(u)du, \quad (8)$$

which equals the face value of debt $B$ adjusted for the loss that creditors expect to incur in default states $[u, u_B]$. (Note that creditors recover $c + x_1$ in case of default.)

With the riskless interest rate at zero, the credit spread, denoted $s$, coincides with the total debt yield, given by

$$s = \frac{B}{D} - 1. \quad (9)$$

### 1.4 Cash holdings and credit spreads

In this subsection, we study the correlation between credit spreads and cash reserves, which arises when they both adjust in response to changes in model parameters.

The effect of any variable $y$ on the credit spread can be decomposed into two components, which we call direct and indirect effects. First, the spread may depend on $y$ directly, for example, because $y$ affects the default boundary and hence the likelihood of default. Second, a change in $y$ may induce a change in the optimal cash reserve $c$, which in turn alters the default boundary and thus affects spreads (an indirect effect through cash).

It is convenient to introduce a special term for variations in cash not induced by changes in credit risk factors. Formally, suppose that cash holdings depend on a variable $y$ that does not affect spreads directly, so that $\partial s/\partial y = 0$. 

In particular, within our model this condition implies that \( y \) does not enter the expression for the default boundary \( u_B \), nor does it affect the distribution of the time-1 cash flow, \( g(u) \). When all other variables are fixed, \( y \) can affect spreads only indirectly, through its effect on cash. We will refer to changes in cash holdings induced by changes in variables that do not affect spreads directly as “exogenous” (to credit risk). By contrast, variations in cash are “endogenous” (to credit risk) if they are induced by changes in credit risk factors. It should be emphasized that an “exogenous” variation in cash need not be due to factors outside the firm’s control. Instead, it can arise as the firm optimally adjusts its cash policy in response to changes in firm characteristics that have no direct effect on credit spreads.

1.4.1 Endogenous variations in cash. A change in many variables that affect spreads directly may also cause cash to adjust in the same direction, so as to undo the direct effect partially. For example, a direct effect of a decline in the expected cash flow is to raise the yield spread. However, optimal cash holdings also increase in response, which in turn decreases the spread (the indirect effect of the drop in cash flow). Other variables, such as the level of debt and the volatility of cash flow, may produce similar effects. This subsection shows that such adjustments in cash can result in a positive correlation between cash holdings and credit spreads in the cross-section.

Let “\( \ast \)” denote the equilibrium values of the variables, so that \( I^\ast \) and \( c^\ast = x_0 - I^\ast \) are the equilibrium levels of investment and cash holdings, and \( s^\ast = s(c^\ast) \) is the credit spread when \( I = I^\ast \). Proposition 1 summarizes the effect of changes in the expected date-1 cash flow, \( \overline{x}_1 \), on cash holdings and spreads (see the Appendix for all proofs):

**Proposition 1.** If the hazard rate \( h(\cdot) \) is non-decreasing, then

1. The equilibrium cash reserve \( c^\ast \) is a decreasing function of \( \overline{x}_1 \);
2. The equilibrium credit spread \( s^\ast \) is a decreasing function of \( \overline{x}_1 \).

When the expected cash flow decreases, the probability of a cash flow shortage at the time of debt repayment increases, so that the direct effect is to make the firm riskier and to raise the credit spread. The first part of Proposition 1 states that the firm’s optimal response is to alleviate the increase in risk by increasing its precautionary savings. This gives rise to the indirect effect of the decrease in cash flow, which is to reduce spreads. The second part of Proposition 1 states that the direct effect dominates, so that, despite their larger cash holdings, firms with lower expected cash flows have higher credit spreads. In practice, this means that when cash flow levels are allowed to vary over time or in the cross-section, this variation can induce a positive correlation between endogenously chosen cash reserves and credit spreads.

To understand why the direct effect dominates, notice that for each dollar of decline in the expected cash flow, the firm increases its cash reserves by less
than a dollar. This can be seen from the first-order condition (6), which balances the marginal cost of cash due to lower investment with its marginal benefit due to lower probability of default. Suppose that the expected cash flow decreases by $1, so that without any adjustments, the default boundary would drop by $1. In response, the firm reduces investment and increases the cash reserve, so that the boundary does not drop as much. However, since the production function is concave and the hazard function $h(\cdot)$ is non-decreasing, for Equation (6) to be satisfied again, investment has to drop by less than $1. Thus, the concavity of the production function makes one-for-one reductions in investment prohibitively costly. As a result, cash holdings increase by less than $1, so that the net effect of the drop in the expected cash flow is to reduce the default boundary and thus to increase the credit spread. The intuition behind this economic mechanism is quite general: If the cost of increasing cash levels to offset higher default risk is convex, the firm offsets default risk only partially, and the direct effect on spreads dominates.\footnote{This discussion underscores the importance of financing constraints. If the firm can pledge a sufficiently high proportion of its long-term cash flow to creditors as collateral, long-term income can play a secondary role as a cash substitute. The marginal cost of cash holdings is then effectively reduced and Proposition 1 may not hold. We discuss the case of partially pledgeability in Subsection 1.6.}

As noted above, similar effects can arise due to variations in firm characteristics other than the cash flow, if they affect both spreads and optimal cash holdings. For example, suppose that the firm’s debt level increases. The direct effect of this increase is to raise spreads. However, optimal cash holdings also rise, which dampens the effect of higher debt levels on spreads. It can be shown that the direct effect dominates, much as in the case of varying expected cash flow in Proposition 1. As a result, more indebted firms have both higher cash levels and higher spreads, implying a positive cross-sectional correlation between the two. Similar effects may also arise when the initial cash flow, $x_0$, is allowed to vary, or when the firm pays a fixed dividend that reduces its net cash flow (see Subsection 1.2).

1.4.2 Exogenous variations in cash. This subsection considers the effect of exogenous variations in cash, which are not induced by changes in credit risk factors. It is easy to show that such cash variations are negatively correlated with credit spreads, consistent with the simple intuition that firms with more cash should be “safer” and have lower spreads.

**Proposition 2.** If $\frac{\partial c}{\partial y} = 0$, then $\text{sign} \left( \frac{\partial s^*}{\partial y} \right) = -\text{sign} \left( \frac{\partial c}{\partial y} \right)$. 

Proposition 2 states that when a factor that is unrelated to credit risk causes cash holdings to increase, credit spreads fall in response. In other words, spreads are negatively related to “exogenous” (to credit risk) changes in cash.
In our empirical analysis, we refer to factors \( y \) that may induce an exogenous variation in cash as *instruments.* To be an instrument, a variable must affect cash holdings without altering creditors’ payoffs or the probability of default other than through changes in cash. Put differently, an instrument would not affect spreads if cash were held constant. Formally, instruments in our model are variables that enter the first-order condition (Equation (6)), but not the expression for the value of debt (Equation (8)). Assuming that external financing cannot be raised against any part of period-2 cash flow, both the cash flow from assets in place, \( x_2 \), and the parameters of the production function, \( f(\cdot) \), satisfy these requirements. Variations in cash induced by changes in these variables would be negatively correlated with spreads.

**Example 1: Growth options.** The long-term cash flow from assets in place, \( x_2 \), can be interpreted as the value of the firm’s growth options. An increase in the growth option increases the value of equity conditional on survival, and hence enhances shareholders’ incentives to conserve cash to avoid default. At the same time, as this cash flow is not collateralizable, it does not benefit short-term creditors directly. Since the growth option does not enter the expression for the value of debt, it affects spreads only indirectly, through the induced variation in cash holdings. It follows from Proposition 2 that the resulting cross-sectional variation in cash is negatively correlated with credit spreads.

More generally, when external financing is not fully prohibited, a fraction of the long-term cash flow can be used as collateral to raise external financing. Anticipating this at \( t=0 \), the firm would substitute some of its cash reserve with future external financing, which would enter the expression for the default boundary and thus affect the probability of default directly. Thus, not every long-term cash flow can provide an instrument. Only variations in the levels of those assets that the firm does not anticipate using as collateral at the time when it chooses its cash holdings (i.e., at \( t=0 \)) can play this role.\(^{12}\) One example of an instrument would be any unanticipated shock to the firm’s cash that occurs between \( t=0 \) and debt maturity.\(^{13}\) As discussed above, non-collateralizable long-term growth options also induce exogenous variations in cash. Other non-collateralizable assets, such as human capital, can play the same role.

In more general settings with multiple classes of debt, some variables can be used as an instrument for some debt obligations, but not for others. For example, if at time \( t \) a firm has two outstanding bonds with different maturities, \( T_1 < T_2 \), then non-collateralizable assets that produce a cash flow between \( T_1 \) and \( T_2 \) do not affect the value of the short-term debt but can affect the cash reserve at \( t \), and hence can be used as an instrument for analyzing the relationship between

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12 We would like to thank the referee for pointing out this property of instruments.

13 For example, if the firm obtains an unexpected settlement in a lawsuit (see Blanchard et al. 1994), its cash reserve increases exogenously and its debt becomes safer as a result of the change in cash.
cash and the short-term credit risk. However, the cash flow from the same assets affects the value of the long-term debt directly (by increasing the amount of cash available at $T_2$), and hence cannot be used as a long-term instrument.14

Example 2: Managerial losses in distress. Another example of a non-collateralizable “asset” is the private benefit that managers derive from avoiding default. Gilson (1989), Baird and Rasmussen (2007), and Ozelge and Saunders (2008) find that upon distress, there is a significantly higher probability of top management dismissal, especially due to direct intervention by lending banks, and that managers dismissed in distress suffer a significant private cost in the form of diminished future employment opportunities. Eckbo and Thorburn (2003) find that in Sweden, where creditor rights include automatic firing of the manager in default, managers of bankrupt companies suffer a median (abnormal) income loss of 47%. Managers’ private costs of distress are likely to depend on the structure of their compensation contracts.15 Differences in managerial compensation across firms should thus result in different incentives for managers to save cash to avoid default, because the private costs differ. As a result, differences in compensation can induce an exogenous variation in cash holdings.

Consider the following extension of the base-case model. Assume that the firm’s risk-neutral manager owns a share $\theta > 0$ of the equity $E$ and incurs a fixed, private cost $\gamma > 0$ if the firm defaults. For a given ownership level $\theta$, the manager’s incentives to retain cash beyond the level that maximizes the value of equity increase with the private cost of distress $\gamma$. Conversely, given $\gamma$, they decline with her ownership of the firm $\theta$. It turns out that the overall effect on the manager’s chosen cash policy depends on the ratio of managerial cost to her equity stake, $\frac{\gamma}{\theta}$, which can be interpreted as a measure of agency problems between the manager and the shareholders. The higher the manager’s private cost of default and the lower her equity stake, the more conservative the firm’s cash policy (relative to one that maximizes the overall value of equity), resulting in lower credit spreads for the same underlying level of credit risk. Formally, the manager’s objective is to choose investment $I$ to maximize

$$ M = \theta \times E - \gamma G(u_B). \tag{10} $$

As shown in the Appendix, this case is technically very similar to that of the variation in $x_2$, and the cross-sectional correlation between cash holdings and spreads induced by variations in the agency factor $\frac{\gamma}{\theta}$ is thus negative.

14 Simutin (2010) also finds that firms with growth options hold more cash. He suggests that if growth options are risky, then cash holdings might be positively related to firm risk. Our model clarifies that firm riskiness induced by growth options may not necessarily be related to credit risk, if on average growth options arrive beyond the maturity of the firm’s debt. Thus, whether cash holdings induced by growth options are independent of the firm’s credit risk depends on the debt’s maturity structure, and is ultimately an empirical question, which we examine in our context in Section 3 below.

15 Managerial incentives have also been shown to be important in studies of capital structure (Carlson and Lazrak 2010) and corporate takeovers (Pinkowitz, Sturgess, and Williamson 2011).
1.5 Cash policy and the probability of default

Another important issue concerns the relationship between cash and the probability of default. In this subsection, we show that the correlation between the two depends on the horizon over which the likelihood of default is measured. Managers choose the optimal cash policy taking into account the probability of default over the long term. By contrast, in the presence of market frictions it is difficult for a distressed firm to adjust its cash balances to desired levels on short notice. Therefore, the relationship between cash and default in the short term should be studied conditional on past cash and investment choices.

In our discrete-time model, the instantaneous probability of default is zero almost everywhere, except for the moment just before the scheduled debt repayment at $t=1$, i.e., after the random cash flow $x_1$ is realized. Whether the firm defaults at that moment depends on the total amount of cash available at that time, which is equal to the sum of the firm’s cash reserve $c$ chosen earlier and the realization of the random cash flow $x_1$. The firm defaults if the total cash amount is smaller than the required debt payment. Thus, ceteris paribus, the instantaneous probability of default is inversely related to the firm’s total cash holdings.

By contrast, for long horizons the endogeneity of cash holdings is crucial. In our model, the long-term probability of default evaluated at date 0, $q$, is given by

$$q = \int_u^u uB g(u) du = G(uB).$$

(11)

To study how cash reserves are related to the probability of default at this point, consider the effect of variation in the date-1 expected cash flow, $\overline{x}_1$. According to Proposition 1, as $\overline{x}_1$ increases, shareholders optimally decrease the cash reserve $c^*$ at $t=0$. Similar to the effect on credit spreads, there are two effects on the probability of default $q$, direct and indirect. On the one hand, a higher expected cash flow results in a lower default probability (the direct effect). On the other hand, a smaller chosen cash reserve means a larger probability of default (the indirect effect). As Proposition 3 shows, the direct effect dominates:

**Proposition 3.** The probability of default evaluated at $t=0$, $q$, is a decreasing function of $\overline{x}_1$.

The intuition is similar to that for the relationship between cash and spreads. As the expected date-1 cash flow increases by $1$, optimal cash reserves decrease by less than $1$ due to the concavity of the production function, so that shareholders are indifferent at the margin between higher investment returns and lower probability of realizing them due to the interim probability of default. Note that, as with the relationship between cash and credit spreads, other parameters (such as the level of debt) can induce the same result.
At the same time, exogenous variations in cash holdings are negatively correlated with the long-term probability of default. Once again, this relationship mirrors that for credit spreads, which is discussed in detail in Section 1.4.2.

1.6 The effect of partial pledgeability
In our base-case model, the firm has no access to external financing. In this subsection, we extend the model to consider the effect of partial pledgeability of future cash flows. Suppose that at $t=1$ the firm can use a fraction $\tau$ of its future cash flow (which equals $f(I)+x_2$) as collateral for new financing, where $0 \leq \tau < 1$. Here, $\tau = 0$ corresponds to our base case of extreme financing frictions, when the firm cannot raise any external financing against its future cash flow, whereas $\tau = 1$ implies frictionless access to external capital.\footnote{One economic interpretation of $\tau$ is that it represents the extent to which future cash flows are verifiable at date 1. Low values of $\tau$ correspond to unverifiable cash flows that are difficult to pledge as collateral to providers of outside finance.}

Conditional on survival, raising new financing at $t=1$ in this setting is value-neutral. Therefore, we can assume without loss of generality that the firm always raises the maximum available amount, $\tau(f(I)+x_2)$. Thus, cash available for debt service at date 1 is $c+x_1+\tau(f(I)+x_2)$, which is the sum of the cash reserve $c$, the random cash flow $x_1 = x_1 + u$, and the newly borrowed amount $\tau(f(I)+x_2)$. The “default boundary,” or the minimum cash flow shock that allows the firm to repay $B$ in full and avoid default, is

$$u_B = B - c_0 - x_1 + I - \tau(f(I)+x_2).$$  \hspace{1cm} (12)

The value of equity can be written as

$$E = \int_{u_B}^{\infty} [(u-u_B)+(1-\tau)(f(I)+x_2)]g(u)du,$$  \hspace{1cm} (13)

where $u-u_B$ is the amount of cash left in the firm after $B$ is repaid, and $(1-\tau)(f(I)+x_2)$ is shareholders’ claim on the period-2 cash flow, conditional on the firm not defaulting in the interim.

As previously, changes in model parameters can affect spreads directly and indirectly. Proposition 4 states that variations in the expected cash flow produce a positive correlation between equilibrium cash holdings and credit spreads, provided that financing constraints are sufficiently binding:

**Proposition 4.** If the hazard rate $h(\cdot)$ is non-decreasing, then

1. The equilibrium cash reserve $c^*$ is a non-increasing function of $x_1$ for any $\tau < 1$;

2. There exists a threshold level of pledgeability $\bar{\tau}$, such that the equilibrium credit spread $s^*$ is decreasing in $x_1$ for any $\tau < \bar{\tau}$.

The first part of Proposition 4 is a generalization of the result obtained earlier for $\tau = 0$. The second part states that there exists a minimum level of financing constraints above which the direct effect of the variation in $x_1$ dominates, so that cash and spreads change in the same direction. Thus, Proposition 1 is a special case of Proposition 4, corresponding to $\tau = 0$. We conclude that our main prediction holds in situations when access to external financing is possible, provided that market frictions are restrictive enough.

It is worth noting that when asset pledgeability $\tau$ is high, an increase in the expected cash flow $x_1$ may for some combinations of functions $f$ and $h$ result in higher credit spreads because of the following “asset substitution” problem. When investment cash flows are highly pledgeable, and when investment productivity is declining only slowly, an increase in the interim cash flow by one dollar can induce an increase in investment by more than a dollar, as shareholders expect to be able to borrow more against a larger pool of collateral at $t = 1$. Thus, the composition of funds available for debt service shifts toward a lower precautionary cash reserve in combination with higher new borrowing. Even though in the new equilibrium the probability of default is lower, in default states creditors’ recovery rates are disproportionately lower, because there is less cash in the firm, and long-term investments have no value in default. Thus, under such scenarios the overall effect of an increase in the expected interim cash flow may be to increase spreads.\[17\]

2. Data Description

This section describes our data and discusses the variables that we use in the empirical tests.

2.1 Data sources and sample composition

Our empirical analysis focuses on credit spreads and the probability of default. We restrict our attention to firms that issue public bonds, because private-debt defaults and credit spreads are difficult to observe. Information on bonds is from the Fixed Income Securities Database (FISD) provided by Mergent. Default data are from Moody’s Default & Recovery Database (DRD), which provides comprehensive information about defaults on rated bonds, including omitted payments, bankruptcy filings, and distressed bond renegotiations. Financial data are from Compustat, executive compensation data are from ExecuComp, and estimates of the expected default frequencies (EDFs) are from Moody’s/KMV (MKMV). Finally, to estimate yield spreads, we use prices of bonds included in the Merrill Lynch U.S. Investment Grade Index and High

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\[17\] Note that incentives to engage in asset substitution disappear in the absence of financing frictions. Indeed, in the limiting case of $\tau = 1$, cash holdings and investment cash flows are perfect time substitutes, so that investment is at its first-best level, and precautionary savings play no role. In this case, a higher expected interim cash flow simply enlarges the total pool of assets without affecting cash holdings, and thus results in lower credit spreads.
Yield Master II Index. The pricing data consist of monthly bid quotes from Merrill Lynch’s bond trading desks, and are only available for a subset of bond issuers.\textsuperscript{18} Our sample extends from December 1996 (the month when the indices were created) to September 2010.

We construct our sample as follows. First, we merge data on non-financial U.S. firms in Compustat with information on bond issuers in FISD, taking account of mergers, acquisitions, name changes, and parent-subsidiary relationships between different bond issuers, and excluding firms that we cannot merge reliably. We thus obtain 2,247 unique firms that had at least one bond outstanding between 1996 and 2010. We use quarterly Compustat data to study the probability of default for these firms. To this end, we search for these firms in the DRD, and find that 541 of them defaulted during the sample period. Overall, the sample consists of 79,932 firm-quarter observations for 2,247 bond issuers at risk of default.

Bond pricing information is available from the Merrill Lynch indices for 1,595 of our firms. To be able to estimate credit spreads accurately, we eliminate non-fixed coupon bonds, asset-backed issues, bonds with embedded options (such as callable, puttable, exchangeable, and convertible securities), and bonds with sinking fund provisions. We also exclude bonds with remaining time to maturity of less than one year or more than thirty years, because risk-free yields that we use to estimate spreads are not available for these maturities. This leaves us with 530 firms, 35,206 firm-months, and 103,691 bond-month observations that we use to estimate bond spreads.

Table 1 shows the composition of our sample, as well as that of the subsample for which spreads are available.\textsuperscript{19} As can be seen from column (1), B-rated firms are the most common in the firm-quarter sample. In total, junk firms (those rated BB+ and lower) comprise 58\% of all firm-quarters. This proportion is substantially smaller for the subsample of firms for which we have spreads. In column (3), junk firms add up to 23\% of the spread subsample, while 68\% of it is concentrated in the two lowest investment-grade categories, A and BBB. The reason why junk firms are underrepresented in the subsample of spreads is that they are more likely to issue callable bonds, which we exclude for the purposes of spread analysis. As we explain below, our main results are driven primarily by risky firms, for which the possibility of a cash shortage looms large. Thus, they would be strengthened if more junk firms issued straight bonds. Overall, the composition of spreads by rating in our subsample of spreads is similar to that documented in other corporate bond and credit default swap data sets.

\textsuperscript{18} The indices include corporate bonds with a par amount of at least 100 million dollars ($250 million for investment-grade bonds after December 2004) and remaining maturity of at least one year.

\textsuperscript{19} The number of firms in each rating class does not stay constant throughout the sample period, because ratings change over time. Statistics reported in columns (1) and (3) of Table 1 show ratings for each firm as of the date when they first appear in the sample. During our sample period, more firms were downgraded than upgraded. As a result, for junk ratings, the proportion of firm-quarters and firm-months in the sample is higher than the proportion of firms.
Table 1
Sample composition by rating

<table>
<thead>
<tr>
<th>Rating</th>
<th>Study of Defaults</th>
<th>Study of Spreads</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Firms (1)</td>
<td>Firm-quarters (2)</td>
</tr>
<tr>
<td>AAA</td>
<td>16</td>
<td>546</td>
</tr>
<tr>
<td>AA</td>
<td>77</td>
<td>2,184</td>
</tr>
<tr>
<td>A</td>
<td>295</td>
<td>11,745</td>
</tr>
<tr>
<td>BBB</td>
<td>383</td>
<td>19,099</td>
</tr>
<tr>
<td>BB</td>
<td>449</td>
<td>15,136</td>
</tr>
<tr>
<td>B</td>
<td>870</td>
<td>24,444</td>
</tr>
<tr>
<td>CCC and below</td>
<td>157</td>
<td>6,778</td>
</tr>
<tr>
<td>Total</td>
<td>2,247</td>
<td>79,932</td>
</tr>
</tbody>
</table>

This table shows the number of unique firms and the number of observations for the full sample (columns (1) and (2)), and for the subsample of firms with straight bonds with observed spreads (columns (3) and (4)), by the firm’s senior unsecured rating. The ratings in columns (1) and (3) are as of the first date that the firm appears in the data set, and in columns (2) and (4) as of the observation date.

Our initial data set is an unbalanced panel of monthly observations of spreads. A potential issue with this data structure is that large firms with many outstanding bonds may be overrepresented in any given month. Because we are interested in the relationship between credit risk and liquid assets, which are firm- rather than bond-specific, using all bond-month observations may bias the results toward large firms. We address this issue by computing the average spread across bonds for a given firm in a given month, and using one observation per firm-month in our analysis. We also use the average bond maturity of all bonds for which spreads are available; all other variables are measured at the firm level. Because spreads are observed at the monthly frequency, but balance sheet information is only available quarterly, in our regressions each observation of a liquidity ratio is used in three different months. This introduces correlation in regression residuals. We account for it by clustering regression residuals at the firm level (Petersen 2009).

Panel A of Table 2 reports descriptive statistics on credit spreads. The mean spread is 224 basis points, and the median is 153 basis points. Unsurprisingly, spreads are higher for lower-rated bonds. Untabulated comparisons suggest

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(e.g., Collin-Dufresne, Goldstein, and Martin 2001; Davydenko and Strebulaev 2007; Schaefer and Strebulaev 2008).

2.2 Statistics on spreads and liquidity ratios

We measure the credit spread as the difference between the bond’s promised yield implied by its price, and the yield on a portfolio of risk-free zero-coupon securities (STRIPS) with the same promised cash flow, as suggested by Davydenko and Strebulaev (2007). This estimation method controls accurately for the shape of the term structure. Our initial data set is an unbalanced panel of monthly observations of spreads. A potential issue with this data structure is that large firms with many outstanding bonds may be overrepresented in any given month. Because we are interested in the relationship between credit risk and liquid assets, which are firm- rather than bond-specific, using all bond-month observations may bias the results toward large firms. We address this issue by computing the average spread across bonds for a given firm in a given month, and using one observation per firm-month in our analysis. We also use the average bond maturity of all bonds for which spreads are available; all other variables are measured at the firm level. Because spreads are observed at the monthly frequency, but balance sheet information is only available quarterly, in our regressions each observation of a liquidity ratio is used in three different months. This introduces correlation in regression residuals. We account for it by clustering regression residuals at the firm level (Petersen 2009).

Panel A of Table 2 reports descriptive statistics on credit spreads. The mean spread is 224 basis points, and the median is 153 basis points. Unsurprisingly, spreads are higher for lower-rated bonds. Untabulated comparisons suggest

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20 In robustness tests, we estimate spreads relative to the swap curve computed using the Nelson-Siegel (1987) algorithm. The spreads estimated in this way are lower, but our qualitative results are not affected in any way. Another alternative would be to use CDS spreads instead of bond spreads.
Table 2
Statistics on credit spreads and liquidity ratios

Panel A: Credit spreads

<table>
<thead>
<tr>
<th>Rating</th>
<th>Mean</th>
<th>Median</th>
<th>25%</th>
<th>75%</th>
<th>Std. Dev.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>2.24</td>
<td>1.53</td>
<td>0.95</td>
<td>2.60</td>
<td>2.18</td>
<td>35,206</td>
</tr>
<tr>
<td>AAA</td>
<td>0.91</td>
<td>0.84</td>
<td>0.62</td>
<td>1.15</td>
<td>0.36</td>
<td>700</td>
</tr>
<tr>
<td>AA</td>
<td>0.87</td>
<td>0.77</td>
<td>0.55</td>
<td>1.05</td>
<td>0.44</td>
<td>2,245</td>
</tr>
<tr>
<td>BBB</td>
<td>1.25</td>
<td>1.09</td>
<td>0.76</td>
<td>1.55</td>
<td>0.71</td>
<td>10,980</td>
</tr>
<tr>
<td>BB</td>
<td>1.96</td>
<td>1.62</td>
<td>1.03</td>
<td>2.28</td>
<td>1.44</td>
<td>13,120</td>
</tr>
<tr>
<td>B</td>
<td>3.61</td>
<td>3.08</td>
<td>2.05</td>
<td>4.46</td>
<td>2.27</td>
<td>5,280</td>
</tr>
<tr>
<td>CCC and below</td>
<td>5.42</td>
<td>4.41</td>
<td>3.02</td>
<td>7.08</td>
<td>3.18</td>
<td>2,158</td>
</tr>
</tbody>
</table>

Panel A reports the annualized bond spread, averaged over all outstanding straight bonds for each firm-month, by firm’s senior unsecured rating. The benchmark risk-free yield is the yield on a cash-flow-matched portfolio of STRIPS. Panel B reports liquidity ratios for the full sample of firm-quarters. TA is the total book assets of the issuing firm. Cash is cash and marketable securities; WC is working capital, CA is current assets, QA is current assets less inventories, and CL is current liabilities.

Table 2
Statistics on credit spreads and liquidity ratios

Panel B: Liquid asset reserves

<table>
<thead>
<tr>
<th>Liquidity Ratio</th>
<th>Mean</th>
<th>Median</th>
<th>25%</th>
<th>75%</th>
<th>Std. Dev.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash/TA</td>
<td>0.071</td>
<td>0.031</td>
<td>0.010</td>
<td>0.088</td>
<td>0.101</td>
<td>79,633</td>
</tr>
<tr>
<td>WC/TA</td>
<td>0.115</td>
<td>0.087</td>
<td>0.001</td>
<td>0.212</td>
<td>0.164</td>
<td>76,600</td>
</tr>
<tr>
<td>CA/CL (current ratio)</td>
<td>1.696</td>
<td>1.446</td>
<td>1.004</td>
<td>2.071</td>
<td>1.073</td>
<td>76,599</td>
</tr>
<tr>
<td>QA/CL (quick ratio)</td>
<td>1.601</td>
<td>0.836</td>
<td>0.543</td>
<td>1.256</td>
<td>0.905</td>
<td>75,458</td>
</tr>
</tbody>
</table>

Panel B of Table 2 summarizes various measures of balance sheet liquidity. To measure liquid asset reserves, we use the cash/assets ratio popular in empirical corporate finance studies, as well as liquidity ratios employed in empirical default-predicting models. Among the best-known models, Altman’s (1968) z-score includes WC/TA, the ratio of working capital (the difference between current assets and current liabilities) to total assets; Zmijewski’s (1984) model and the ZETA-score model of Altman, Haldeman, and Narayanan (1977) use the current ratio CA/CL (current assets over current liabilities); and Ohlson (1980) and Chava and Jarrow (2004) use both WC/TA and CL/CA to proxy for liquidity. Davydenko (2012) uses the quick ratio, QA/CL, equal to current assets less inventories, over current liabilities. The quick ratio is similar to the current ratio, but does not consider inventories to be part of liquid asset holdings, because distressed firms may find it difficult to convert their inventories into

that for a given rating, spreads typically increase with maturity. It is interesting to note that the average BB spread (361 basis points) is almost twice as high as that for BBB bonds (196 basis points). This jump in the spread is likely attributable to not only the increase in the probability of default but also the lower liquidity of speculative-grade bonds (BB+ and below) compared with investment-grade bonds.21

21 Potentially, the lower liquidity of speculative-grade bonds may be a concern in our analysis. However, if the illiquidity component in the credit spread is not highly varying within each rating group, its effect on our regression estimates should be minimal. See Schaefer and Strebulaev (2008) for a discussion of the impact of illiquidity.
Figure 2
Cash holdings by rating: Bond issuers
This graph shows means and medians of the ratio of cash to total assets by the firm’s senior unsecured rating. The sample consists of all firm-quarters for non-financial U.S. firms that had bonds outstanding between December 1996 and September 2010.

cash. Panel B shows that our firms have lower cash reserves on average than those in the broader Compustat samples typically used in empirical studies of cash holdings. For instance, in Opler et al. (1999), the mean (median) ratio of cash to assets is 17% (6.5%), compared with 7.1% (3.1%) in our sample. These differences arise in part because our sample does not include firms with zero or near-zero leverage, which tend to hold significant amounts of cash (Strebulaev and Yang 2012), and in part because bond issuers are likely to be less financially constrained and value cash holdings less than an average Compustat firm (which should work against our finding of any effects related to the optimally chosen cash policy). Our tests on a broad set of Compustat firms (see the discussion of Figure 3 below) confirm that our main results are likely to be even stronger for them, as they are more financially constrained and thus more concerned about internal cash reserves.

Figure 2 summarizes cash holdings by credit rating; we obtain similar results when we use other measures of credit risk (e.g., the interest coverage ratio). The graph shows that cash is roughly U-shaped in the firm’s credit quality. Safe AAA and AA firms have higher-than-average cash holdings and low debt levels. Their high balance sheet liquidity and low net leverage are likely important reasons for why rating agencies rate them so highly in the first place. For such firms, the risk of default is unlikely to be a leading factor shaping their cash policy. However, at the other end of the ratings spectrum, speculative-grade (junk)
firms (those rated below BBB–) also have higher-than-average cash holdings, and lower grades of junk generally correspond to higher cash reserves. We argue that this pattern is due to levered firms’ precautionary motives for saving cash. Despite their relatively high cash reserves, these firms remain riskier than A- or BBB-rated firms because of their much higher levels of debt relative to their cash flows. Indeed, even relatively high cash holdings of 3.6% of net assets for the median B-rated firm fade to insignificance next to its debt level, which is close to 50% of assets. Overall, in the cross-section, firms with lower credit ratings (and thus a higher probability of default) have higher cash holdings. As a result, cash turns out to be positively associated with credit spreads, with a stronger relationship for riskier firms.

To confirm that these results are not limited to public bond issuers, we look at the cash holdings of all non-financial firms in the annual Compustat file since 1950 (341,954 firm-years for 24,825 firms). Because most of these firms lack a credit rating, we use the interest coverage ratio (EBIDTA divided by the interest expense) as a proxy for credit risk. We also split the sample into firms with high and low financing constraints, depending on whether the index of constraints suggested by Hadlock and Pierce (2010) is higher or lower than its median for the year. Figure 3 plots the means of the cash-to-asset ratio for each decile of the interest coverage ratio, from the 10th (safest) to the 1st (riskiest), separately for constrained and unconstrained firms.

Several results stand out. First, the U-shaped relationship between cash and credit risk holds beyond our sample of bond issuers. In particular, cash holdings increase sharply as firms become very risky. Second, for a given level of credit risk, financially constrained firms hold more cash than unconstrained firms. This finding is consistent with the conjecture that firms with better access to external financing (i.e., unconstrained) need to worry less about maintaining a cash reserve as a precautionary measure.22 Third, the levels of cash for an average Compustat firm are substantially higher than those for our bond-issuing firms, consistent with lower financing constraints for bond issuers making internal cash reserves less important. Many corporate finance studies classify firms that issue bonds and have a credit rating as relatively unconstrained (e.g., Almeida, Campello, and Weisbach 2004). By focusing on these firms, we are biasing ourselves against finding a role for an endogenous cash policy. Nonetheless, our results show that even for rated bond issuers, the precautionary motive for saving cash is a first-order determinant of the relationship between liquid assets and credit risk.

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22 In an unreported test, we also produce a version of Figure 2, separating constrained and unconstrained firms. We find that, while the cash holdings of investment-grade bond issuers are similar for both groups, they are higher for constrained speculative-grade firms than those of unconstrained firms with the same rating. This finding is consistent with the precautionary motive being stronger for constrained firms when the risk of default is high.
Cash/Assets

Deciles of the Interest Coverage Ratio

High constraints
Low constraints

Figure 3
Cash holdings by interest coverage: All Compustat firms
For each decile of the interest coverage ratio, this graph plots the mean of the cash-to-asset ratio among financially constrained and unconstrained firms. The sample consists of all firm-years for non-financial U.S. firms included in annual Compustat between 1950 and 2011. The interest coverage ratio is the sum of pretax income, depreciation & amortization, and interest expense, divided by interest expense. In each year, firms are classified as constrained (unconstrained) if the Hadlock-Pierce index of financial constraints is above (below) its median for that year.

2.3 Control variables
Table 3 presents descriptive statistics on the control variables used in regressions of spreads and default probabilities, which we borrow from extant empirical research.

Based on insights from structural models of credit risk, empirical studies of spreads control for leverage, volatility, debt maturity, and various macroeconomic factors, in particular those related to the term structure of interest rates (e.g., Collin-Dufresne, Goldstein, and Martin 2001). We estimate the (quasi-market) leverage ratio as the book value of total debt divided by the sum of the book value of debt and the market value of equity. Another factor featuring prominently in credit risk models is the volatility of assets, which we estimate as a weighted average of the three-year volatility of equity and the volatility of debt by rating, as suggested by Schaefer and Strebulaev (2008). To further control for the effects of volatility and leverage beyond the simple linear dependence, we include the distance to default, which is a volatility-adjusted measure of leverage based on the Merton (1974) model of credit risk. Specifically, we use the simplified (“naïve”) distance to default measure suggested by Bharath and Shumway (2008), which they find to outperform other, more sophisticated proxies. To control for the term premium in corporate bond yields, we use the average remaining time to maturity of all sample bonds.
Table 3
Statistics on control variables

Panel A: Determinants of credit spreads

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Median</th>
<th>25%</th>
<th>75%</th>
<th>Std. Dev.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>TA, $ billion</td>
<td>16.94</td>
<td>7.66</td>
<td>3.39</td>
<td>18.98</td>
<td>33.68</td>
<td>35,203</td>
</tr>
<tr>
<td>Leverage</td>
<td>0.324</td>
<td>0.287</td>
<td>0.160</td>
<td>0.456</td>
<td>0.205</td>
<td>31,079</td>
</tr>
<tr>
<td>Asset volatility</td>
<td>0.239</td>
<td>0.226</td>
<td>0.179</td>
<td>0.283</td>
<td>0.088</td>
<td>29,762</td>
</tr>
<tr>
<td>Bond maturity, yrs</td>
<td>5.993</td>
<td>5.674</td>
<td>3.375</td>
<td>8.313</td>
<td>4.069</td>
<td>20,757</td>
</tr>
<tr>
<td>Risk-free rate, %</td>
<td>5.048</td>
<td>5.060</td>
<td>4.340</td>
<td>5.800</td>
<td>0.939</td>
<td>35,206</td>
</tr>
<tr>
<td>Slope, %</td>
<td>0.851</td>
<td>0.430</td>
<td>0.100</td>
<td>1.860</td>
<td>0.934</td>
<td>35,206</td>
</tr>
<tr>
<td>VIX</td>
<td>0.23</td>
<td>0.23</td>
<td>0.19</td>
<td>0.25</td>
<td>0.067</td>
<td>34,821</td>
</tr>
<tr>
<td>S&amp;P return, %</td>
<td>0.66</td>
<td>1.00</td>
<td>−2.15</td>
<td>4.35</td>
<td>4.773</td>
<td>35,206</td>
</tr>
<tr>
<td>Jump</td>
<td>0.043</td>
<td>0.048</td>
<td>0.029</td>
<td>0.057</td>
<td>0.025</td>
<td>35,206</td>
</tr>
</tbody>
</table>

Panel B: Determinants of the default probability

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Median</th>
<th>25%</th>
<th>75%</th>
<th>Std. Dev.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>RE/TA</td>
<td>0.044</td>
<td>0.108</td>
<td>−0.038</td>
<td>0.265</td>
<td>0.447</td>
<td>75,266</td>
</tr>
<tr>
<td>EBIT/TA</td>
<td>0.019</td>
<td>0.021</td>
<td>0.009</td>
<td>0.033</td>
<td>0.032</td>
<td>71,942</td>
</tr>
<tr>
<td>ME/TA</td>
<td>1.988</td>
<td>1.153</td>
<td>0.579</td>
<td>2.264</td>
<td>2.635</td>
<td>65,100</td>
</tr>
<tr>
<td>N/TA</td>
<td>0.255</td>
<td>0.210</td>
<td>0.119</td>
<td>0.327</td>
<td>0.192</td>
<td>79,746</td>
</tr>
<tr>
<td>NI/TA</td>
<td>0.005</td>
<td>0.009</td>
<td>0.000</td>
<td>0.018</td>
<td>0.031</td>
<td>79,758</td>
</tr>
<tr>
<td>TL/TA</td>
<td>0.690</td>
<td>0.659</td>
<td>0.542</td>
<td>0.785</td>
<td>0.253</td>
<td>79,897</td>
</tr>
<tr>
<td>EDF, %</td>
<td>2.221</td>
<td>0.390</td>
<td>0.096</td>
<td>1.603</td>
<td>4.648</td>
<td>55,825</td>
</tr>
<tr>
<td>z-score</td>
<td>1.688</td>
<td>1.350</td>
<td>0.713</td>
<td>2.250</td>
<td>1.816</td>
<td>53,575</td>
</tr>
</tbody>
</table>

This table reports summary statistics on control variables used in regressions of spreads (Panel A) and the probability of default (Panel B). TA is the total book value of assets. Leverage is the book value of total debt divided by the sum of the book value of debt and the market value of equity. Asset volatility is the annualized standard deviation of asset returns, estimated as suggested by Schaefer and Strebulaev (2008). Distance to default is a volatility-adjusted measure of leverage computed using the simplified approach of Bharath and Shumway (2008). Bond maturity is the remaining bond maturity in years on the observation date averaged over all bonds with available spreads. Risk-free rate is the 10-year constant-maturity rate, and slope is the difference between the 10-year and the 2-year Treasury rates. Jump is the option-implied measure of market jumps, constructed as in Collin-Dufresne et al. (2001). RE is retained earnings, ME is the market value of equity, S is sales, NI is net income, TL is the book value of total liabilities, and EDF is the Expected Default Frequency provided by MKMV.

outstanding for the firm at each observation date. We include the logarithm of total book assets to control for all influences that the firm’s size may exert on debt spreads. In some of the regressions, we also use dummies for the firm’s senior unsecured credit rating (AAA, AA+, AA, AA–, …, C), which summarizes the credit agency’s opinion of the firm’s creditworthiness and incorporates not only its financial characteristics but also industry conditions and other, frequently soft, information.

Finally, Collin-Dufresne, Goldstein, and Martin (2001) find that a significant part of monthly changes in spreads is driven by systematic factors. We follow their study in controlling for the risk-free interest rate (using the 10-year constant-maturity Treasury rate), the slope of the yield curve (the difference between 10- and 2-year Treasury rates), the VIX index to control for market-wide volatility, the monthly S&P 500 return, and Jump, an option-implied proxy for the probability and magnitude of a large negative jump in value.23

23 Following Collin-Dufresne, Goldstein, and Martin (2001), we construct the variable Jump as follows. First, from the OptionMetrics database, we obtain Black-Scholes volatility estimates for at- and out-of-the-money
Empirical default-predicting models identify a large number of accounting- and market-based variables related to default. We reestimate two of the best-known models, those of Altman (1968) and Zmijewski (1984), as well as one that uses the Expected Default Frequency (EDF) from MKMV. Altman’s \( z \)-score includes \( WC/TA \) (the liquidity proxy), as well as \( RE/TA \) (Retained Earnings over Total Assets), \( EBIT/TA \) (Earnings Before Interest and Tax over Total Assets), \( ME/TL \) (equity market capitalization over Total Liabilities), and \( S/TA \) (Sales over Total Assets). Zmijewski’s model includes the current ratio \( CA/CL \) as the liquidity proxy, \( NI/TA \) (Net Income over Total Assets), and \( TL/TA \) (Total Liabilities over Total Assets). Finally, we estimate a simple model that uses the quick ratio \( QA/CL \) as the liquidity proxy and the \( EDF \) from MKMV as a summary measure of credit risk. MKMV estimates the EDF based on the firm’s equity prices and liability structure using a version of the Merton (1974) model in conjunction with a proprietary data set of defaults (Crosbie and Bohn 2001). Hillegeist et al. (2004) and Bharath and Shumway (2008) show that variants of this variable are strong predictors of default. As is common in such studies, we winsorize all variables at the first and 99th percentiles.

Table 3 shows that our firms are relatively large in size, with median total book assets of almost $7.7 billion. This is to be expected, given that all of them issue public bonds. They also have relatively high leverage ratios compared with broad Compustat samples not conditioned on the presence of public bonds in the capital structure. Statistics on leverage and asset volatility are similar to those in other studies of spreads (e.g., Schaefer and Strebulaev 2008). Looking at firm characteristics by rating (not reported), we find that firms with higher ratings are larger, less levered, and more profitable; have slightly larger capital expenditures; and return substantially more cash to shareholders via dividends and repurchases than do riskier firms. Comparing the values of Altman’s (1968) and Zmijewski’s (1984) default factors with those reported in Shumway (2001), our firms appear more distressed than the average Compustat firm—again, likely because of the presence of bonds, which implies higher-than-average leverage ratios.

3. Cash Holdings and Credit Spreads

This section studies the relationship between balance sheet liquidity and bond spreads. First, we show that standard OLS regressions similar to those used in empirical studies of spreads appear to suggest that higher cash holdings result in higher spreads. Then, we use instrumental variables suggested by the model, and demonstrate that in IV regressions, higher cash holdings correspond to lower spreads.

\begin{align*}
\text{puts and at-} & \text{and in-the-money calls on the S&P 500 futures with shortest maturities. Second, we estimate the regression } & \sigma(K) = a + bK + cK^2, \text{ where } K \text{ is the strike price. Third, for each month-end, we compute } \text{Jump}= & \\
& \{\sigma(0.9F) - \sigma(F)\}, \text{ where } F \text{ is the current futures price.}
\end{align*}
Cash Holdings and Credit Risk

In these tests, the dependent variable is the bond spread relative to a cash-flow-matched portfolio of Treasuries, averaged across all of the firm’s outstanding bonds for each date. To proxy for balance sheet liquidity, we use the ratio of cash to total assets, as well as working capital over total assets (as in Altman’s [1968] z-score), and the current ratio, equal to current assets over current liabilities (as in Zmijewski 1984), although many other proxies yield similar results.

The regression results are presented in Table 4. The effect of standard credit risk factors is in line with economic intuition and corroborates evidence from other studies of spreads (e.g., Davydenko and Strebulaev 2007). More levered, more volatile, and smaller firms are riskier and consequently have higher credit spreads. Similar to Collin-Dufresne, Goldstein, and Martin (2001), we also find the macroeconomic controls to be robustly significant and consistent with expectations. Interestingly, adding rating dummies increases the R-squared noticeably even after controlling for firm-specific credit risk using leverage and volatility proxies (from 53%–55% to 63%–65%). Thus, though ratings provide an admittedly crude summary of credit risk (as evidenced by the strong significance of leverage and volatility in columns (4), (6), and (9)), they clearly have significant incremental explanatory power.

Our focus is on the effect of liquid assets. The results reported in Table 4 contradict the simple intuition that firms with larger liquid asset reserves are “safer” and thus should have lower spreads. Both in univariate regressions and in the presence of standard credit risk controls, the correlation between credit spreads and liquidity is positive and strongly statistically significant, typically at the 1% level. The implied economic effect is also considerable: In columns (1), (4), and (7) of Table 4, a one-standard-deviation increase in the three liquidity ratios corresponds to an increase in the bond spread of 18, 15, and 20 basis points, respectively. The positive relationship between credit spreads and liquidity proxies persists even after controlling for the credit rating. Moreover, in untabulated tests, we estimate specification (2) separately for different ratings groups, and find that the coefficient for cash is increasing monotonically as the rating deteriorates.

These results are robust in the data and insensitive to the way the control variables are constructed. They are nearly identical if cash is measured as a fraction of assets net of cash, rather than total assets, or if, instead of Schaefer and Strebulaev’s (2008) proxy for asset volatility, we use the asset volatility estimate provided by MKMV. They are strengthened if we use book instead of market leverage. One could hypothesize that cash holdings are affected by covenants restricting liquidity levels, which in turn are correlated with the underlying credit risk. However, such covenants are infrequent in practice (Dichev and Skinner 2002). Using data on bank loans from DealScan, we find that only 1.6% of our firms have loan covenants specifying minimum liquidity ratios (current or quick ratio). In addition, for 2.9% of firms covenants restrict capital expenditures, which also may affect cash reserves. In unreported
OLS regressions of bond spreads

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>t-stat</th>
<th>Prob</th>
<th>(R^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash/TA</td>
<td>3.28***</td>
<td>(3.14)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WC/TA</td>
<td>2.52***</td>
<td>(4.31)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CA/CL</td>
<td>1.21***</td>
<td>(2.67)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leverage</td>
<td>6.53***</td>
<td>(15.1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asset volatility</td>
<td>7.47***</td>
<td>(11.3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log(Assets)</td>
<td>-0.036***</td>
<td>(-5.73)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance to default</td>
<td>0.0014</td>
<td>(-0.10)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maturity</td>
<td>0.036***</td>
<td>(5.96)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk-free rate</td>
<td>-0.47***</td>
<td>(-31.7)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TS slope</td>
<td>-0.083**</td>
<td>(-2.48)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIX</td>
<td>2.98***</td>
<td>(7.81)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S&amp;P return</td>
<td>-0.020***</td>
<td>(-9.93)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jump</td>
<td>4.10***</td>
<td>(8.25)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rating dummies</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adj. (R^2)</td>
<td>0.0%</td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

The dependent variable is the annualized yield spread relative to a cash-flow-matched portfolio of STRIPS, averaged over all outstanding bonds for each firm-month observation in the sample. TA is the book value of total assets, WC is working capital, CA is current assets, and CL is current liabilities. Leverage is the book value of total debt divided by the sum of the book value of debt and the market value of equity. Asset volatility is the annualized standard deviation of asset returns, estimated as suggested by Schaefer and Strebulaev (2008). Distance to default is a volatility-adjusted measure of leverage computed using the simplified approach of Bharath and Shumway (2008). Bond maturity is the remaining bond maturity in years on the observation date averaged over all bonds with available spreads. Risk-free rate is the 10-year constant-maturity rate, and slope is the difference between the 10-year and the 2-year Treasury rates. Jump is the option-implied measure of market jumps, constructed as in Collin-Dufresne et al. (2001). The values of t-statistics adjusted for clustering at the firm level are reported in parentheses. Coefficients marked ***, **, and * are significant at the 1%, 5%, and 10% significance levels, respectively.
tests we find that controlling for the presence of such covenants has no impact on our results.24

Our model suggests that the positive correlation of spreads with liquid assets arises as a by-product of the precautionary motive for holding cash reserves in levered firms, which results in riskier firms having both more cash and higher credit spreads. In essence, cash reserves act as another proxy for credit risk. Thus, our theory would predict that as we introduce more credit risk controls, the positive coefficient should decrease. This is what we observe in Table 4. For example, compared with column (1), the coefficient for Cash/TA is lower in column (2), which controls for leverage, volatility, and other factors. In column (3), which also controls for ratings, it is reduced further. Nonetheless, it retains strong statistical significance. Thus, standard OLS regressions used in empirical studies of spreads appear inadequate for studying the role of factors such as cash, which are subject to endogenous corporate financing decisions.

The model also predicts that exogenous variations in cash (those not induced by differences in credit risk factors) should be negatively related to spreads. We test this prediction using instrumental variable regressions. Our model suggests two potential instruments. First, profitable future investment opportunities (growth options) increase the value of the firm in the absence of default, and hence strengthen the precautionary motive for saving cash. Yet once the higher cash reserve is in place, it provides a safety cushion for creditors, decreasing credit spreads. The discussion of growth options in Section 1.4.2 suggests that it is the variations in non-collateralizable assets that can serve as an instrument for cash in our model. Accordingly, to proxy for growth options, we use the median ratio of intangible to total assets in the firm’s three-digit SIC industry in each calendar year.25

Second, the model suggests the ratio of managerial private costs of financial distress to the fraction of the firm’s equity that the manager owns as another instrument. The higher this fraction, the higher the manager’s incentives to hoard cash (above the level that maximizes the value of equity) to avoid default and the associated private costs. We assume that the CEO’s salary and bonus are at risk if the firm defaults. Accordingly, our agency term is the ratio of CEO’s salary, bonus, and other monetary compensation, to the market value of her shares and options, estimated using the ExecuComp database.26

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24 See Murfin (2012) for a recent study of the determinants of bank loan covenants.

25 We prefer intangibles to the market-to-book ratio as a proxy for growth opportunities, because in addition to other well-known problems with market-to-book (Erickson and Whited 2000), in our setting, it is also mechanically correlated with the market leverage ratio, which renders it unsuitable as a potential instrument. We use an industry-based measure of intangibles to avoid endogeneity concerns.

26 Specifically, the agency term is defined as (salary + bonus + other annual compensation + long-term incentive plan + all other compensation) / (value of the equity stake + value of all unexercised options owned) for the CEO. As ExecuComp reports the Black-Scholes value of new option grants but not the current value of previously granted options, we employ the algorithm suggested by Himmelberg and Hubbard (2000) to estimate the market value of old options.
We employ these two instruments in IV regressions of spreads that mirror the regressions of Table 4, with the same proxies for liquid asset reserves and the same standard control variables. The results are presented in Table 5. The last row reports the $p$-value of the $F$-test of the instruments’ relevance. It shows that our two instruments are jointly strongly significant determinants of the liquidity ratios. The table shows that, as expected, exogenous variations in liquid asset reserves are negatively and significantly related to bond spreads. Moreover, the economic effect of higher liquid reserves is substantial: In full-specified regressions (3), (6), and (9), a one-standard-deviation increase in the instrumented liquidity ratios decreases spreads by between 37 and 53 basis points.

Thus, the simple intuition that higher cash holdings make firms safer, implying a negative relationship between cash and spreads, is correct. However, to uncover this intuitive result, the empiricist must overturn the effect of the endogeneity of cash, which strongly dominates in standard OLS regressions commonly used in empirical studies of credit risk. These findings show that accounting for the fact that firms can choose their cash holdings optimally is of first-order importance for understanding the relationship between liquid assets and credit risk.

4. Balance Sheet Liquidity and the Probability of Default

Most empirical default-predicting models include some proxies for balance sheet liquidity, treating them as independent variables expected to reduce the probability of default. However, despite the intuitive appeal and the widespread use of liquidity ratios in this context, Begley, Ming, and Watts (1996), Shumway (2001), and Hillegeist et al. (2004), as well as Ohlson (1980) and Zmijewski (1984) in their original work, find them unrelated to or even positively associated with default. In this section, we look at how the endogeneity of cash affects the correlation between liquid asset reserves and the probability of default.

The standard approach in the literature is to identify a set of factors expected to affect the probability of default, and, taking them as given, estimate some variant of a hazard model of default or bankruptcy. Shumway (2001) shows that discrete-time hazard regressions are equivalent to logit regressions that include all firm-quarter observations for each firm, defaulting and non-defaulting. Thus, we estimate a set of logit regressions of default for different prediction horizons using our panel of quarterly observations for the full sample of 2,247 firms. For the horizon of $m$ years, the dependent variable is equal to one if the firm defaults in the $m$th year from the observation date, but not before. Under this regression

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27 Staiger and Stock (1997) show that when the correlation between instruments and endogenous variables is weak, IV regression coefficients may be biased. They suggest that the $F$-statistic of the hypothesis that the instruments do not enter the first-stage regression should be sufficiently large to avoid the weak-instrument bias. In our univariate regressions of Table 5, these statics range from 15 to 26, although they are smaller in multivariate tests.
The dependent variable is the annualized yield spread relative to a cash-flow-matched portfolio of STRIPS, averaged over all outstanding bonds for each firm-month observation in the sample. The proxies for balance sheet liquidity (Cash/TA, WC/TA, and CA/CL) are instrumented with the ratio of intangible to Total Assets of the median firm in the same three-digit SIC industry in each quarter, and with the Agency term, defined as the ratio of the CEO’s salary and bonus to the value of her equity holdings and options in the firm. TA is the book value of total assets, WC is working capital, CA is current assets, and CL is current liabilities. Leverage is the book value of total debt divided by the sum of the book value of debt and the market value of equity. Asset volatility is the annualized standard deviation of asset returns, estimated as suggested by Schaefer and Stolarz (2008). Distance to default is a volatility-adjusted measure of leverage computed using the simplified approach of Bharath and Shumway (2008). Bond maturity is the remaining bond maturity in years on the observation date averaged over all bonds with available spreads. Risk-free rate is the 10-year constant-maturity rate, and slope is the difference between the 10-year and the 2-year Treasury rates. Jump is the option-implied measure of market jumps, constructed as in Collin-Dufresne et al. (2003). The values of t-statistics adjusted for clustering at the firm level are reported in parentheses. Coefficients marked ***, **, and * are significant at the 1%, 5%, and 10% significance levels, respectively. The last row reports the p-value of the F-test of the hypothesis that the instruments do not enter the first-stage regression.

### Table 5

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash/TA</td>
<td>−14.9***</td>
<td>−29.7***</td>
<td>−17.0***</td>
<td></td>
<td>−1.62**</td>
<td>−2.83**</td>
<td>−1.33**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WC/TA</td>
<td>(−2.15)</td>
<td>(−2.01)</td>
<td>(−1.79)</td>
<td></td>
<td>(−1.97)</td>
<td>(−2.35)</td>
<td>(−1.80)</td>
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<td></td>
</tr>
<tr>
<td>CA/CL</td>
<td>−7.08**</td>
<td>−13.3**</td>
<td>−5.88**</td>
<td></td>
<td>−6.58**</td>
<td>−10.79**</td>
<td>−6.12**</td>
<td></td>
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</tr>
<tr>
<td>Leverage</td>
<td>8.10***</td>
<td>2.73***</td>
<td>6.23***</td>
<td>2.07***</td>
<td>6.41***</td>
<td>2.17***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asset volatility</td>
<td>(0.39)</td>
<td>(4.97)</td>
<td>(7.64)</td>
<td>(3.63)</td>
<td>(7.85)</td>
<td>(6.63)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log(Assets)</td>
<td>(0.92)</td>
<td>(2.72)</td>
<td>(5.20)</td>
<td>(0.39)</td>
<td>(5.42)</td>
<td>(0.15)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maturity</td>
<td>0.074***</td>
<td>0.060***</td>
<td>0.066***</td>
<td>0.053***</td>
<td>0.078***</td>
<td>0.060***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk-free rate</td>
<td>(3.76)</td>
<td>(4.99)</td>
<td>(5.53)</td>
<td>(5.46)</td>
<td>(5.53)</td>
<td>(4.91)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance to default</td>
<td>0.12**</td>
<td>−0.022</td>
<td>0.044</td>
<td>−0.050***</td>
<td>0.041</td>
<td>−0.049***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S&amp;P return</td>
<td>(0.31)</td>
<td>(0.36)</td>
<td>(0.99)</td>
<td>(5.70)</td>
<td>(0.87)</td>
<td>(0.50)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TS slope</td>
<td>−0.36***</td>
<td>−0.089</td>
<td>−0.29**</td>
<td>−0.050</td>
<td>−0.30***</td>
<td>−0.054</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIX</td>
<td>(−4.15)</td>
<td>(−3.26)</td>
<td>(−5.26)</td>
<td>(−3.91)</td>
<td>(−5.21)</td>
<td>(−3.60)</td>
<td></td>
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<tr>
<td>S&amp;P return</td>
<td>(−0.028***</td>
<td>−0.012***</td>
<td>−0.026**</td>
<td>−0.011***</td>
<td>−0.030***</td>
<td>−0.012***</td>
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<tr>
<td>Jump</td>
<td>4.24***</td>
<td>4.91***</td>
<td>4.75***</td>
<td>5.35***</td>
<td>5.03**</td>
<td>5.48***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rating dummies</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Const.</td>
<td>3.10***</td>
<td>0.86</td>
<td>1.66</td>
<td>2.78***</td>
<td>6.95***</td>
<td>3.63*</td>
<td>4.47***</td>
<td>11.0***</td>
<td>5.51*</td>
</tr>
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<td>24,743</td>
<td>20,261</td>
<td>20,261</td>
<td>23,431</td>
<td>19,123</td>
<td>19,123</td>
<td>23,431</td>
<td>19,123</td>
<td>19,123</td>
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<tr>
<td>Adj. R²</td>
<td>0.8%</td>
<td>54.7%</td>
<td>65.3%</td>
<td>65.7%</td>
<td>65.2%</td>
<td>65.7%</td>
<td>65.2%</td>
<td>65.7%</td>
<td>65.2%</td>
</tr>
<tr>
<td>Instr. P-value</td>
<td>0.000</td>
<td>0.050</td>
<td>0.045</td>
<td>0.005</td>
<td>0.000</td>
<td>0.005</td>
<td>0.000</td>
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<td>0.000</td>
</tr>
</tbody>
</table>

The dependent variable is the annualized yield spread relative to a cash-flow-matched portfolio of STRIPS, averaged over all outstanding bonds for each firm-month observation in the sample. The proxies for balance sheet liquidity (Cash/TA, WC/TA, and CA/CL) are instrumented with the ratio of intangible to Total Assets of the median firm in the same three-digit SIC industry in each quarter, and with the Agency term, defined as the ratio of the CEO’s salary and bonus to the value of her equity holdings and options in the firm. TA is the book value of total assets, WC is working capital, CA is current assets, and CL is current liabilities. Leverage is the book value of total debt divided by the sum of the book value of debt and the market value of equity. Asset volatility is the annualized standard deviation of asset returns, estimated as suggested by Schaefer and Stolarz (2008). Distance to default is a volatility-adjusted measure of leverage computed using the simplified approach of Bharath and Shumway (2008). Bond maturity is the remaining bond maturity in years on the observation date averaged over all bonds with available spreads. Risk-free rate is the 10-year constant-maturity rate, and slope is the difference between the 10-year and the 2-year Treasury rates. Jump is the option-implied measure of market jumps, constructed as in Collin-Dufresne et al. (2003). The values of t-statistics adjusted for clustering at the firm level are reported in parentheses. Coefficients marked ***, **, and * are significant at the 1%, 5%, and 10% significance levels, respectively. The last row reports the p-value of the F-test of the hypothesis that the instruments do not enter the first-stage regression.
design, prediction horizons for different firm-quarters overlap, which may bias conventional test statistics. Thus, to compute the standard errors in these tests, we use bootstrap, estimating each regression for 1,000 panels resampled from firm-level clusters.28

The results are presented in Table 6. Panel A uses the variables that enter Altman’s (1968) z-score model, including \( \frac{WC}{TA} \), the ratio of working capital to total assets, as a proxy for liquidity. Panel B employs the specification suggested by Zmijewski (1984), which includes the current ratio to control for liquid assets. Panel C uses a different proxy for liquidity, the quick ratio (Davydenko 2012), and controls for other credit risk factors by including the Expected Default Frequency (EDF) from MKMV, variations of which have been frequently used in recent empirical studies.

While the effect of most variables is consistent with expectations and prior studies (e.g., Shumway 2001), the effect of liquidity proxies changes depending on the prediction horizon. The regressions in column (1) of Table 6 are for the one-year probability of default. At this horizon, in all three models the liquidity ratios are negatively correlated with the probability of default. Depending on the model, a one-standard-deviation increase in the liquidity ratio reduces the probability of default by between one quarter (Panels A and B) and one-third (Panel C).29 These results are consistent with Davydenko (2012), who finds that, controlling for the level of economic distress, the short-term probability of default is higher when the firm’s liquid assets fall short of its current liabilities, and that the importance of illiquidity relative to insolvency in triggering default depends on the level of financing constraints.

In contrast with the short-term results, columns (2) through (4) of Table 6 show that liquidity is positively related to the probability of default at the two- to five-year horizons, and the coefficients are strongly statistically significant. The coefficients are broadly similar in magnitude to those in column (1), but have the opposite sign—implying similar economic significance, but in the wrong direction. A more detailed illustration of this sign reversal for the Zmijewski model is provided in Figure 4. It plots the coefficient for the current ratio, \( \frac{CA}{CL} \), in regressions of Panel B, estimated for quarterly rather than yearly prediction intervals (i.e., predicting default within a certain quarter in the future, rather than within a certain year). The graph shows that liquidity is negatively correlated with the probability of default for horizons of up to approximately one year, but the correlation reverses its sign and becomes highly statistically significant for longer-term predictions. In our model, equilibrium cash reserves are driven by the precautionary motive for saving cash, and the long-term

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28 See Horowitz (2001) for a detailed discussion of bootstrap procedures. We thank Andrew Karolyi (the editor) for alerting us to these issues, and Mitch Petersen and Tyler Shumway for their advice on statistical inference under our empirical test design.

29 King and Zeng (2001) show that when the event of interest is rare (as is the case in studies of default), standard quantitative predictions in logit regressions are biased in finite samples. Thus, to compute the marginal effect of cash on the probability of default, we employ the correction for the bias proposed in their study.
Table 6
Liquid assets and the probability of default at different horizons

<table>
<thead>
<tr>
<th></th>
<th>Logit</th>
<th>IV GLS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 year</td>
<td>2 years</td>
</tr>
<tr>
<td>Panel A: Altman’s (1968) Z-score</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WC/TA</td>
<td>−1.46***</td>
<td>1.01***</td>
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<tr>
<td>(−3.73)</td>
<td>(3.34)</td>
<td>(4.69)</td>
</tr>
<tr>
<td>RE/TA</td>
<td>−0.30**</td>
<td>−0.37***</td>
</tr>
<tr>
<td>(−2.55)</td>
<td>(−4.24)</td>
<td>(−5.90)</td>
</tr>
<tr>
<td>EBIT/TA</td>
<td>−13.49***</td>
<td>−7.71***</td>
</tr>
<tr>
<td>(−14.48)</td>
<td>(−8.35)</td>
<td>(−5.37)</td>
</tr>
<tr>
<td>ME/TL</td>
<td>−4.47***</td>
<td>−1.21***</td>
</tr>
<tr>
<td>(−10.70)</td>
<td>(−8.00)</td>
<td>(−3.72)</td>
</tr>
<tr>
<td>S/TA</td>
<td>0.26</td>
<td>−0.33</td>
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<tr>
<td>(0.84)</td>
<td>(−1.17)</td>
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<tr>
<td>Const.</td>
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<td>−2.65***</td>
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<tr>
<td>(−9.37)</td>
<td>(−22.05)</td>
<td>(−27.06)</td>
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<tr>
<td>N</td>
<td>53,575</td>
<td>53,575</td>
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</tbody>
</table>

Panel B: Zmijewski’s (1984) model

<table>
<thead>
<tr>
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<th>Lagit</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 year</td>
<td>2 years</td>
</tr>
<tr>
<td>CA/CL</td>
<td>−0.22***</td>
<td>0.20**</td>
</tr>
<tr>
<td>(−3.86)</td>
<td>(6.38)</td>
<td>(9.34)</td>
</tr>
<tr>
<td>N/TA</td>
<td>−17.33***</td>
<td>−9.14***</td>
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<tr>
<td>(−28.74)</td>
<td>(−15.19)</td>
<td>(−8.36)</td>
</tr>
<tr>
<td>TL/TA</td>
<td>2.31***</td>
<td>1.86***</td>
</tr>
<tr>
<td>(17.16)</td>
<td>(15.74)</td>
<td>(12.91)</td>
</tr>
<tr>
<td>Const.</td>
<td>−5.50***</td>
<td>−5.53***</td>
</tr>
<tr>
<td>(−35.96)</td>
<td>(−41.80)</td>
<td>(−38.92)</td>
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<tr>
<td>N</td>
<td>76,439</td>
<td>76,439</td>
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</table>

Panel C: EDF-based model

<table>
<thead>
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<th>IV GLS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 year</td>
<td>2 years</td>
</tr>
<tr>
<td>QA/CL</td>
<td>−0.36***</td>
<td>0.15***</td>
</tr>
<tr>
<td>(−3.01)</td>
<td>(2.68)</td>
<td>(4.14)</td>
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<tr>
<td>EDF</td>
<td>0.19***</td>
<td>0.11***</td>
</tr>
<tr>
<td>(29.27)</td>
<td>(22.22)</td>
<td>(13.31)</td>
</tr>
<tr>
<td>Const.</td>
<td>−4.75***</td>
<td>−4.36***</td>
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<tr>
<td>(−36.02)</td>
<td>(−46.90)</td>
<td>(−44.47)</td>
</tr>
<tr>
<td>N</td>
<td>52,939</td>
<td>52,939</td>
</tr>
</tbody>
</table>

This table reports logit regressions (columns (1)–(4)) and instrumental-variable logit regressions (columns (5)–(7)) of bond defaults at different prediction horizons. In regression (1), the dependent variable equals 1 if the firm defaults within the following year, and 0 otherwise. In regressions (2) through (7), the dependent variable equals 1 if the firm defaults in a given year from the observation date, but not before. WC is working capital, TA is the book value of total assets, CA is current assets, CL is current liabilities, QA is current assets less inventories, RE is retained earnings, ME is the market value of equity, TL is the book value of total liabilities, S is sales, NI is net income, and EDF is the Expected Default Frequency provided by MKMV. Each regression is estimated using 1,000 bootstrapped samples from firm-level clusters; the resulting z-statistics are reported in parentheses. Coefficients marked ***, **, and * are significant at the 1%, 5%, and 10% significance levels, respectively.

default probability is positively correlated with liquidity. This contrast with the simple intuition that traditional default-predicting studies rely on implicitly, which only holds for short horizons.\[^{30}\]

\[^{30}\] In the continuous-time model that we develop in the online appendix, the firm makes debt coupon payments continuously, which allows us to study the term structure of default probabilities theoretically in more detail.
The Review of Financial Studies

Figure 4

Liquid assets and the probability of default at different horizons

This graph shows the point estimate and the 95% confidence interval for the logit regression coefficient for CA/CL in Zmijewski’s (1984) model, for different prediction horizons. For a horizon of m quarters, the dependent variable equals one if the firm defaults in the mth quarter from the observation date, and zero otherwise. The regressions also include NI/TA and TL/TA as control variables. The sample consists of 76,349 firm-quarter observations. The confidence interval is obtained by bootstrapping from firm-level clusters.

Consistent with the hypothesized effect of endogeneity, columns (5)–(7) of Table 6 show that the sign of the liquidity coefficients in long-term regressions becomes negative when we use the instrumental variables introduced in Section 3. The instrumented liquidity ratios are all negative, and statistically significant for horizons of three years or more.

Overall, these tests suggest that the effect of balance sheet liquidity on the probability of default for horizons longer than a few quarters cannot be captured adequately by a standard approach that treats liquid assets as given. We thus emphasize once again the importance of recognizing that firms can choose their cash policy endogenously, depending in particular on credit risk.

5. Concluding Remarks

In this paper, we document a robust positive correlation of corporate cash holdings with credit spreads and with the long-term probability of default. These findings run contrary to the simple intuition that higher cash reserves make corporate debt “safer.” We argue that they arise because firms’ cash holdings respond endogenously to the possibility of a liquidity shortage, which in the presence of restrictions on external financing can trigger costly default.

model predicts that a long-term default probability is positively correlated with cash, in a way that is qualitatively similar to our empirical findings in Figure 4.
Cash Holdings and Credit Risk

Our model shows how such effects can arise when future cash flows are only partially pledgeable and when default is costly. At the same time, exogenous variations in the firm’s cash holdings that are unrelated to credit risk factors are negatively correlated with spreads. The simple intuition that predicts that firms with high cash holdings should be safer can account only for the direct relationship between cash and spreads. It misses the indirect relationship that is due to the endogeneity of cash, which, as our evidence suggests, dominates in practice. An important implication is that recognizing that balance sheet liquidity is endogenous is crucial for credit risk studies, which is a key effect largely ignored in existing literature. More generally, our findings highlight the importance of adopting the corporate finance perspective in asset-pricing studies of the firm. Otherwise, using most common variables, such as corporate liquidity proxies, in some of the most standard tests, such as predictive regressions of default, may yield misleading results due to spurious correlations.

Appendix: Proofs of Model Propositions

Proof of Proposition 1. Define function \( m(I^*, \tau_1) \), where \( I^* \) is the optimal investment level from the first-order condition (6), as

\[
m(I^*, \tau_1) = f(I^*) - 1 - (f(I^*) + x_2)h(u_B). \tag{A1}
\]

**Part 1.** Because \( c^* = x_0 - I^* \),

\[
\frac{dc^*}{d\tau_1} = -\frac{dI^*}{d\tau_1} = -\left( -\frac{\partial m}{\partial \tau_1} \right). \tag{A2}
\]

The second-order condition of optimization implies that \( \frac{\partial m}{\partial \tau_1} \leq 0 \), as

\[
\frac{\partial m}{\partial \tau_1} = f''(I^*) - f'(I^*)h(u_B) - (f(I^*) + x_2)h'(u_B), \tag{A3}
\]

which is negative because \( f'' < 0 \) and \( h' \geq 0 \). Also,

\[
\frac{\partial m}{\partial x_1} = -(f(I^*) + x_2)h'(u_B)\frac{\partial u_B}{\partial x_1} > 0, \tag{A4}
\]

because \( \frac{\partial u_B}{\partial x_1} = -1 \). Therefore, \( \frac{\partial c^*}{\partial \tau_1} \leq 0 \).

**Part 2.** Equations (8) and (9) imply that

\[
\frac{\partial s}{\partial \tau_1} = -\frac{B}{D^2} \frac{\partial D}{\partial \tau_1} = -\frac{B}{D^2} G(u_B), \tag{A5}
\]

and

\[
\frac{\partial s}{\partial c^*} = -\frac{B}{D^2} \frac{\partial D}{\partial c^*} = -\frac{B}{D^2} G(u_B). \tag{A6}
\]

Therefore,

\[
\frac{ds}{d\tau_1} = \frac{\partial s}{\partial \tau_1} + \frac{\partial s}{\partial c^*} \frac{dc^*}{d\tau_1} = -\frac{B}{D^2} G(u_B) \left( 1 + \frac{dc^*}{d\tau_1} \right). \tag{A7}
\]
Because $\frac{\partial c^*}{\partial x_1} \leq 0$, for this quantity to be negative, it is sufficient to establish that $\frac{\partial c^*}{\partial x_1} > -1$. From Equation (A2),

$$\frac{dc^*}{dx_1} = \frac{(f(I^*)+x_2)h(u_B)}{f''(I^*)-f'(I^*)h(u_B)-(f(I^*)+x_2)h'(u_B)},$$

(A8)

The right-hand side of this equation is greater than $-1$ as

$$f''(I^*)-f'(I^*)h(u_B) < 0.$$  \hspace{1cm} (A9)

Therefore, $\frac{dc^*}{dx_1} < 0$. \hfill ■

**Proof of Proposition 2.** Because $\frac{\partial s}{\partial y} = 0$, it follows that

$$\frac{ds}{dy} - \frac{\partial s}{\partial c^*} \frac{dc^*}{dy} = \frac{\partial s}{\partial c^*} \frac{dc^*}{dy}. \hspace{1cm} (A10)$$

In the proof of Proposition 1, we showed that

$$\frac{\partial s}{\partial c^*} = -BD_2 \frac{\partial D}{\partial c^*} = -BD_2 G(u_B) < 0.$$ \hspace{1cm} (A11)

Therefore, the sign of $\frac{ds}{dy}$ is the opposite of the sign of $\frac{dc^*}{dy}$. \hfill ■

**Proof of Proposition 3.** Since $q = G(u_B)$, we can write

$$\frac{dG(u_B)}{dx_1} = g(u_B) \frac{du_B}{dx_1}. \hspace{1cm} (A12)$$

From (2), $I^* = u_B + x_1 - B + x_0$. Define function $n(u_B, x_1)$ as

$$n(u_B, x_1) = m(I^*(u_B), x_1) = f'(u_B + x_1 - B + x_0) - 1 - (f(u_B + x_1 - B + x_0) + x_2)h(u_B).$$ \hspace{1cm} (A13)

It follows that

$$\frac{du_B}{dx_1} = -\frac{\frac{dn}{dx_1}}{\frac{du_B}{dx_1}}.$$ \hspace{1cm} (A14)

where

$$\frac{\partial n}{\partial x_1} = f''(\cdot) - f'(\cdot)h(u_B) < 0,$$ \hspace{1cm} (A15)

and

$$\frac{\partial n}{\partial u_B} = f''(\cdot) - f'(\cdot)h(u_B) - (f(\cdot) + x_2)h'(\cdot) < 0,$$ \hspace{1cm} (A16)

so that $\frac{du_B}{dx_1} < 0$. \hfill ■

**Proof of Proposition 4.** From (12) and (13), the first-order condition can be written as

$$f'(I) = \frac{1+(1-r)(f(I)+x_2)h(\psi_B)}{1+r(1-r)(f(I)+x_2)h(\psi_B)} h(u_B).$$ \hspace{1cm} (A17)

Similar to the proof of Proposition 1, define function $m(I^*, x_1)$, where $I^*$ is the optimal investment level from the first-order condition (A17), as

$$m(I^*, x_1) = f'(I^*) - \frac{1+(1-r)(f(I^*)+x_2)h(u_B)}{1+r(1-r)(f(I^*)+x_2)h(u_B)}.$$ \hspace{1cm} (A18)
Cash Holdings and Credit Risk

Part 1. Because \( c^* = c_0 - I^* \),

\[
\frac{dc^*}{dT_1} = -\left( -\frac{\partial u_B}{\partial \tau_1} \right) \quad (A19)
\]

The second-order condition of optimization implies that \( \frac{d^2 m}{dT_1^2} \leq 0 \). To see it, rewrite it as

\[
\frac{d^2 m}{dT_1^2} = f''(I^*) - \frac{(1-\tau)^2(f'(I^*)h(u_B)+c_0f(I^*+x_2)h'(u_B)(1-\tau f'(I^*)))}{(1+\tau(1-\tau)f(I^*+x_2)h(u_B))^2}, \quad (A20)
\]

which is non-positive because \( f'' < 0 \), \( h' > 0 \), and Equation (A17) implies that \( f'(I^*) < \frac{1}{\tau} \). Also,

\[
\frac{d^2 m}{dT_1^2} = \frac{(1-\tau)^2(f'(I^*)+x_2)h'(u_B)(1-\tau f'(I^*)))}{(1+\tau(1-\tau)f(I^*+x_2)h(u_B))^2} > 0, \quad (A21)
\]

because \( \frac{d^2 m}{dT_1^2} = -1 \). Therefore, \( \frac{d^2 m}{dT_1^2} \leq 0 \).

Part 2. Equations (8) and (9) imply that

\[
\frac{ds}{dT_1} = -\left( -\frac{B}{D^2} \frac{dD}{dT_1} \right) = \frac{B}{D^2} (G(u_B)+g(u_B)\tau (f(I^*+x_2)). \quad (A22)
\]

and

\[
\frac{ds}{dc^*} = -\left( -\frac{B}{D^2} \frac{dD}{dc^*} \right) = -\frac{B}{D^2} (G(u_B)+g(u_B)\tau (f(I^*+x_2)-\tau^2 (f(I^*)+x_2))f'(I^*)g(u_B)). \quad (A23)
\]

Therefore,

\[
\frac{ds}{dT_1} = \frac{\partial x}{\partial T_1} \frac{\partial x}{\partial c^*} \frac{\partial c^*}{\partial T_1} = -\frac{B}{D^2} (G(u_B)+g(u_B)\tau (f(I^*+x_2))\left(1+\frac{\partial c^*}{\partial T_1}\right) + \frac{B}{D^2} \tau^2 (f(I^*+x_2))f'(I^*)g(u_B) \frac{\partial c^*}{\partial T_1}. \quad (A24)
\]

Because \( \frac{\partial c^*}{\partial T_1} \leq 0 \), for this quantity to be negative, it is sufficient to establish that \( \frac{\partial c^*}{\partial T_1} > -1 \). From Equation (A2),

\[
\frac{\partial c^*}{\partial T_1} = \frac{(1-\tau)^2(f'(I^*)+x_2)h'(u_B)(1-\tau f'(I^*)))}{(1+\tau(1-\tau)f(I^*+x_2)h(u_B))^2} \quad (A25)
\]

The right-hand side of this equation is greater than \(-1\) if and only if

\[
Z(\tau) = f''(I^*) - f'(I^*) (1-\tau f'(I^*))^2 (h(u_B) - \tau (f(I^*)+x_2)h'(u_B)) < 0. \quad (A26)
\]

Recall from the proof of Proposition 1 that \( Z(0) = f''(I^*) - f'(I^*) (h(u_B) < 0 \). Because \( Z(\tau) \) is continuous in \( \tau \), there exist \( \tau > 0 \) such that for all \( \tau < \tau \), the condition (A26) is satisfied. \Halmos
Growth Options and Managerial Losses

Proposition A1. The equilibrium level of cash holdings $c^*$ is positively related to the growth option $x_2$. The credit spread $s$ is negatively related to the growth option $x_2$ only through the change in the optimal cash balance.

Proof of Proposition A1. Similar to the proof of Proposition 1, we can write that

$$\frac{dc^*}{dx_2} = -\left( -\frac{\partial m}{\partial x_2} \frac{\partial m}{\partial I} \right),$$

where $m(I^*, \tau_1)$ is defined in (A18). As we established earlier, $\frac{\partial m}{\partial x_2} < 0$. By taking the derivative, $\frac{\partial m}{\partial x_2} = -h(u_B) < 0$, and therefore $\frac{dc^*}{dx_2} > 0$. This establishes the first result in the proposition.

The result on credit spread follows because $\frac{\partial s}{\partial x_2} = 0$ by assumption, and, as shown earlier, $\frac{\partial s}{\partial c} < 0$. ■

Proposition A2. The equilibrium level of cash holdings $c^*$ is positively related to the agency parameter $\gamma \theta$. The credit spread $s$ is negatively related to the agency parameter $\gamma \theta$ only through the change in the optimal cash balance.

Proof of Proposition A2. The first-order condition for maximizing the manager’s objective function (10) can be written as

$$\frac{\partial M}{\partial I} = \theta \int_{u_B}^{\infty} \left[ -1 + f'(I) \right] g(\psi) d\tau_1 - \left[ -1 + (c_0 + \tau_1 + u_B - B) + f(I) \right] g(u_B) - \frac{\partial u_B}{\partial I} - \gamma g(u_B) \frac{\partial u_B}{\partial I} = 0,$$

which results in a condition identical to the first-order condition (7), with $x_2$ replaced by $\gamma \theta$. The result then follows from applying the proof of Proposition 1.

■

References


Cash Holdings and Credit Risk


